Augmenting Interactivity of Low-fidelity Paper Prototypes

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하 세 용

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Abstract

Augmenting Interactivity of low-fidelity paper prototypes

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Today's user interface design is characterized by the rapid and iterative design process. This implies a user test in each iteration steps with a prototype because the feedbacks from the user test lead the increasing in quality of user interface. Through the iteration steps, many types of prototypes are used for user tests. For instance, in an early phase of design process, low-fidelity prototypes are used because it is cheap in cost and easy to make. Among the low-fidelity prototypes, a wireframe has been widely used in the early phase of user interface design process. However, because it lacks interactivity in usage, it is rarely possible to give a realistic experience to user. This thesis describes the design, implementation, and user

evaluation of a sketch-based prototyping tool that augments interactivity of low-fidelity prototype.

Through the literature review, we researched the limitations of current prototyping tools. And then, we obtained findings that provide design implications in developing a prototyping system in the preliminary study. Based on these studies, we designed the prototyping tool for mobile application user interface prototype. The tool consists of a mobile application and Neo1 digital pen and template papers. Designers draw a wireframe prototype on template papers with Neo1 digital pen, and then convert the prototype into mobile device for running. The pen-and-paper interaction technology, called *.Code* technology, lets designers with quick and easy drawing and linking user interfaces. With boxing, anchoring, and linking interaction, designers make the links between user interface screens that represented on a mobile application.

Finally, we present the user evaluation results. We conducted user evaluation with eight participants with two prototyping tasks. We collected the user feedbacks in-task session and after-task session. These results provide both positive and negative results that our tool is quite useful for interactive prototyping and still our tool has some drawbacks in interaction techniques to refine in the future research.

Keyword : Interactive Prototype, Low-fidelity, Wireframe, Pen interaction

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1. INTRODUCTION

When designing user interfaces, it is almost impossible to design perfectly from the start [Nielsen, 1993]. Even if someone has expertise in user interface design, he/she expand times and effort on completing the user interface design. For this reason, it is recommended for designers to follow an iterative design process in user interface design because it lets designers continuously get feedbacks of the design. These feedbacks help designers find the usability problems that are found in the later stages. To conclude, an iterative design reduces the cost in development and improves the quality of the user interface. Therefore, getting valuable feedbacks is important in an iterative design. To get more valuable feedbacks from users, it is suggested to provide a prototype that is similar with intended design product in visual and functional aspects. This prototype allows users experience the intended user interface.

As the iterative design process progresses, different types of prototypes are used. The types of prototypes are classified by its level of fidelity. The term fidelity indicates how a prototype appears to users. Thus, a high-fidelity prototype means the prototype which is very close to the final product in its visual and functional aspects. It is fully interactive and provides almost complete functionalities. Since it depicts nearly complete user interface, designers should consider from design details to interactivity.

Therefore, the cost of building a high-fidelity prototype is much higher than a building low-fidelity prototype. Furthermore, it is hard for designers to make and participate in building the high-fidelity prototype because it is generally builds upon a computer programming to make an interactive prototype. For this reason, a high-fidelity prototype is generally used at the last moment of user interface design process in order to evaluate usability and system functionality [Rettig, 1994; Rudd, 1996]

In contrast, a low-fidelity prototype can be described as sketchy and incomplete rather than the system which provides full functionalities and user interactions. It is usually built with the paper-materials or low-cost materials, so it is cheap in cost, quick to build, and easy to refine [Rettig, 1994; Rudd, 1996; Synder, 2003]. The major disadvantages of the low-fidelity prototype are interactivity and functionality. Since it is usually built with papers, it is not possible to produce fully working interactivity and functionality. This makes users not see alone what the user interface is supposed to do when conducting usability testing [Rudd, 1996; Synder, 2003]. In spite of these disadvantages, low-fidelity prototype catches usability problems almost as many as a high-fidelity prototype does [Virzi, 1996]. Therefore, a low-fidelity is used at an early stage of iterative design process for proof of concept [Synder, 2003].

Among the low-fidelity prototypes, a wireframe is widely used in an early stage of design process. A wireframe is a visual representation of user interfaces including an information architecture, an arrangement of user interface elements, and a navigation of user interface screen. Since a wireframe is drawn by a pen on paper or on a whiteboard, a wireframe lacks in giving interactivity to users, like other low-fidelity prototypes. To test user interactions with a wireframe, another people are required to respond the test user's interactions like paper-prototyping. By responding to test users' every single interaction, designers can get proper feedbacks of the design; however, this method has in trouble with giving realistic experience of user [Synder, 2003]. Thus, if we could increase the interactivity of the low-fidelity prototype, we expect more valuable feedbacks which may not be found in an early stage.

In this study, we propose the new prototyping tool that gives interactivity in an early phase of design process. We focused on a mobile application user interfaces design. In designing mobile user interfaces, designers use a wireframe prototype frequently to present both a user interface layout and an information architecture. We expect our prototyping tool augments the interactivity so that designers get more valuable feedbacks. By adopting the *.Code* technology, we can support the designers' natural sketching behavior.

The rest of the papers describe the concepts of our prototyping tool and evaluations. In section 2, previous research about increasing interactivity in low-fidelity prototyping was identified through the literature reviews. Also, we looked through the pen interaction research to find the way of giving interactivity naturally in sketching a wireframe phase. In section 3, we approach the behavior of sketching and building paper-prototypes from a user research. An observation and a post-interview were conducted in order to derive findings. These findings bring us to design the interaction techniques of new prototype tool. Next two chapters describe the prototype tool's technical details. Section 4 describes the concept of prototyping tool with the details of the each interaction techniques necessary to support designers' natural sketching behaviors. Section5 contains the implementation details of suggested prototyping tool. Then, we will introduce and discuss the result of user evaluation with eight participants which assess the performance and usefulness of the prototyping tool. The evaluations were carried out with two prototyping tasks and post-questionnaire. The evaluation result shows that our prototyping tool is quite intuitive, but has some difficulties to refine. Finally, Chapter 7 concludes the current research and suggests the future directions of current research.

2. RELATED WORK

This section is consists of two parts. First, we reviewed a pen-and-paper interaction using the Anoto[1] technology. Since the Anoto technology is similar to the *.Code*[2] technology, we researched to get a pen-and-paper interaction idea. Second, we introduced the research of low-fidelity prototyping tools. The prototyping tools varied from the web application to mobile application. We found how the previous tool supports low-fidelity prototyping and what kind of constraints previous prototyping tools have.

2.1 PEN INTERACTIONS.

The Anoto technology is the novel pen-and-paper interaction technology. It tracks the user's pen movement on paper by identifies special patterns on paper using the camera embedded in a digital pen. Lots of pen-and-paper interaction research have been conducted based on this technology. In 2003, Guimbretière introduced the pen-and-paper editing framework, called PADD, using the Anoto technology [Guimbretière, 2003]. In his work, he suggested the way of manipulating a digital document in both on a computer and on paper. 'Paperproof' could apply the insertion on a paper-document to a digital document [Weibel, 2008]. By adopting a pen gesture recognition technology, it could support more editing behavior such as deletion,

[1] See the http://www.anoto.com

[2] See the http:/neolab.kr

insertion, and annotation. This work provides evidence that drawings on paper could eliminate the additional efforts to digitize the contents in a paper-document. NiCEBook is another tools for document editing. It focuses on not only managing the information on the paper but also creating a digital note [Peter, 2010].

From the work mentioned above, we discovered the possibility of the creating interactive paper of digital version with the pen-and-paper interaction. However, the interactions used in the previous work did not have any well-formed standards. CoScribe is the one that set up the framework for pen-and-paper interactions and developed an application based the framework [Steimle, 2009]. In the research, Steimli designed the pen interactions by two levels: semantic and syntactic, and defined conceptual interaction with a paper.

2.2 PROTOTYPING TOOL

Available tools for low-fidelity prototyping have become diverse as computer technology has been developed. The Storyboard tool in Xcode application allows designers make an interactive prototyping with little programming skills. If offers not only the static image with high-fidelity but also the interactive prototype, which can operate in the iPhone device.

Balsamiq mockup tool lets people make a prototype by simple drag-and-drop interaction. Balsamiq mockup tool supports pre-defined low-fidelity user interface elements; it makes people focus on the functionalities or information flow more. It also supports powerful export function. Designers can quickly export their static prototype into images or predefined file type. Then, they can share their prototype with other team members with easy. Also, designers test their prototype on a computer. Designers can make links between the user interfaces and run the prototype on the desktop application.

AxureRp is another drag-and-drop interaction based prototyping tool. With AxureRP, designers can build the HTML-based interactive prototype. Moreover, because designers can import the jQuery library to this interactive prototype, they can implement more interaction in the prototype. Also, AxureRP provides a format for documentation, which makes the communication easy between team members.

Unlike the previous two tools, POP application was built for mobile application only. POP application is the sketch-based low-fidelity prototyping tool that supports designers testing their user interface sketches on a mobile device. Designers photographs the user interface sketches using a camera embedded in a mobile device, then makes links between the area they select and other photographed paper prototype. It allows people assess paper prototypes in actual devices.

However, Balsamiq mockup tool and AxureRP cannot support the low-fidelity prototype drawing. Designers make the prototype only with pre-defined user interface elements, if they want to use their own user interface design, they should draw the user interface in other drawing software. And then, import it into the prototyping tool. Balsamiq mockup tool and AxureRp test the prototype only in the application or HTML environment only, so they are not suit for designing application for other environment such as mobile or tabletop-application. Even though the POP application makes an interactive prototype from the sketches and allows designers test the prototype in a mobile environment, it still requires designers doing extra behaviors such as photographing or resizing photos.

Alongside the industrial product, there has been research in the academia. SILK was the first prototyping tools that allow designers able to build an interactive prototype quickly by using an electronic pad and a stylus pen [Landay, 1996]. Contrary to other mockup tools, SILK preserved rough sketches of user interfaces so that designers create a prototype without considering design details, and designers can mark a transition between screens at the same time. Similarly, DENIM is the system that helps designers in the early stage of design, but it was only for a website design [Newman, 2000]. In DENIM system, designers can express their web designs at different refinement levels: site map; storyboard; individual page.

Bolchini et al proposed a "Paper in screen" prototyping method which digitizes each paper-prototype by photographing and creates an album of the captured images on a mobile device [Bolchini, 2009]. This prototype does not support full user interactions; however, users are able to complete a prepared task within an actual context of usage. Mobidev, originally built to help an application development in emerging countries. It converts photos of mobile user interface sketches to an actual mobile device application by computer vision technology [Seifert, 2011]. With Mobidev, user can convert a paper-prototype into a high-fidelity prototype. UISKEI are sketch-based prototyping tool that supports early stage of design process. With a sketch-based interaction, UISKEI supports various UI components, and it allows a user to define user-behavior upon an event-condition-action structure [Segura, 2012].

As presented, previous work proposed a way of building prototypes using photos, digitized sketches, or higher technology. These approaches, however, require extra work for such as a photographing or a digitizing of the interface drawings. Also, in order to make interactivity of the drawings, designers should work on the prototyping software. Our prototyping tool does not require the extra behaviors and designers can check their wireframe prototype and test it on a mobile device instantly.

3. PRELIMINARY USER STUDY

In order to understand how designers work on prototyping, we conducted a preliminary user study. We wanted to understand how designers use sketches to build a wireframe prototype and what the primary factors are in prototyping. The following sections contain a description and findings of interviews and observations.

3.1. METHODOLOGY

Six designers from four different companied were participated in this research (F=4, M=2). Participants were aged from 27-30, having at least one year of experience in either user interface design or user experience design field. The observations and interviews were carried out in a constrained environment. Participants were asked to complete two tasks. First, we asked to (i) draw 5 to 7 mobile application user interface sketches, which they have designed before. Then, we asked to make a paper-prototype with papers on the basis of their first task output. After completing the whole tasks, follow-up interviews were carried out. All interviews were semistructured approaches with questions about prototyping. For example, “Can you tell me when to use paper-prototyping?” “What kind of tools have been used instead of paper-prototyping?” or “What is your purpose of a paper-prototyping?” All the observations and interview data were transcribed to provide detailed actions and verbal utterance.

3.2. FINDINGS

Findings from user study showed several characteristics of designers’ activities in sketching and prototyping. Also, we could get comments about why designers use electronic tools and the important aspects of prototyping.

3.2.1. SKETCHING AND PROTOTYPING

When drawing user interface elements, designers expressed the user interface abstractly using a rectangular shaped element. Since the object of prototyping in early phase was not inspecting design details, they did not represent the user interface layout in detail. Also, we found that a drawing sequence of rectangle was varied by each designer. Figure 1 shows how drawing sequence was varied. They were varied from one to four strokes.

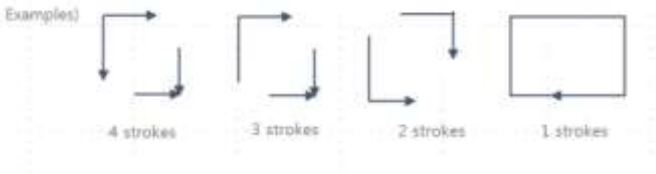

FIGURE 1. THE SEQEUNCE OF DRAWING RECTANGLE

Basically, designers represented the user interaction with the ‘tap’ interaction. Although they considered other interactions at that moment, such as ‘long press’, ‘flipping’, ‘swiping’, they didn’t illustrated that interaction. Instead, they represented other interactions by sketching button elements or annotating them in spare part of the template page (Figure 2). For example, they illustrated the ‘swipe’ gesture by drawing two brackets at the both side of the UI.

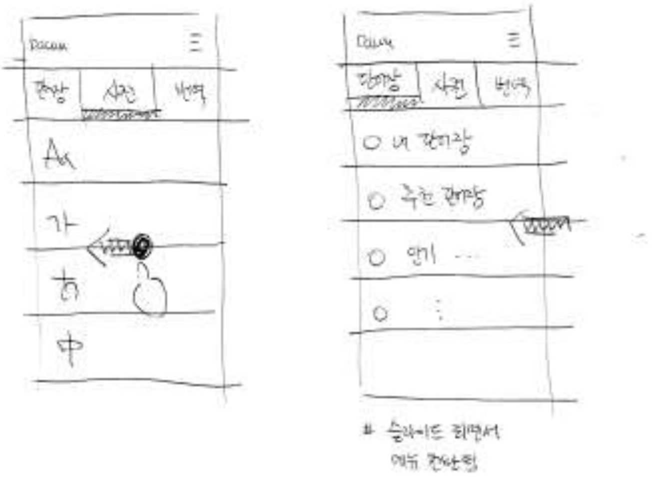

FIGURE 2. ANNOTATING AND PRESENTING A USER INTERACTION

In the sketching activity, designers represented the flow of user interface by marking arrows between each user interface screens. Designers represented the relationships between the user interface component which is intended to touch by user and the user interface screen that will show when the corresponding user interface component was touched. By designing the user interface flow, they could draw up an outline of the user interface design (Figure 3).

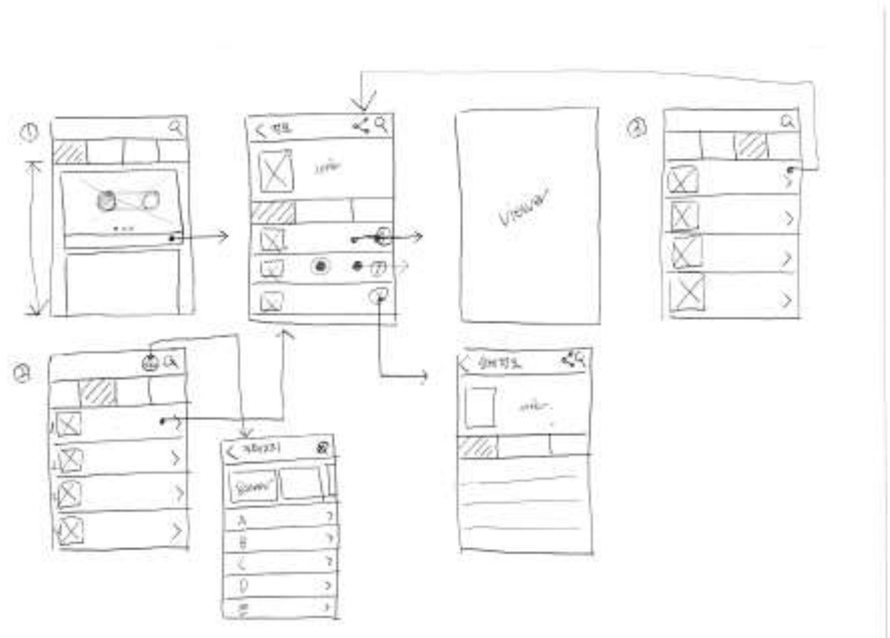

FIGURE 3. A WIREFRAME REPRESENTING INFORMATION FLOW USING ARROWS

3.2.2. INTERVIEWS

Most of the designers said that they build a low-fidelity prototype in order to check user’s interaction flow before moving on to a next phase in an early design stage. This finding forced us to provide a function which is similar with zooming function in the DENIM [Newman, 2000] tool to review an overall user interaction flow.

In the interviews, designers said that they did not use prototyping method often. Although all of them agreed with that they draw user interface sketches on the paper at first, but they use the tools like PowerPoint or Keynote for prototyping in the end. One of them said:

"*We know that the prototype made by the PowerPoint software was not good enough to present a feeling of users' interaction. The PowerPoint documents, however, are much more comfortable to share among team members, even if the team members are far from designers.*" – Subject 1 & 5

Because they mostly build prototypes when they work with team members or clients, sharing and distributing are decisive to them. Thus, if certain prototype is difficult to share or deliver, they would not use the prototype. The designers said that the paper-prototype is not suitable to give the feelings of user interaction. With PowerPoint, designers could present the interactions using animation effect embedded in PowerPoint tool, however it takes too long to present the animation effects. The following quote from one designer underlines this finding:

"*Although I worked with PowerPoint, both PowerPoint- based prototypes and paper-based prototypes could not give me the real user interaction that in my imaginations. In this perspective, I didn't do user test without an interactive prototype that engineer built.*" – Subject 6

3.3. DESIGN IMPLICATION

The results of the observations showed that interactions in a prototype had not been defined from the start. For example, designers used the brackets to represent the ‘swipe’ interaction is available. That marks mean that they have not decided whether to use ‘swipe’ interaction yet. Thus, as a prototyping tool in a very early design process, we need to focus on the ‘tap’ interaction most.

During the mobile application user interface design, designers consider the user interface flow first. Because there are lots of screen transition in a mobile application. User interface designers should consider the information flow, whether the users recognize and accept it or not.

Therefore, since the screen transition is the basis of presenting information architecture, and the ‘tap’ interaction is the most considerable interaction of all interaction. Our prototyping tool focuses on supporting screen transitions by touch actions.

4. SYSTEM DESIGN

Through the section 2 and 3, we have reviewed the previous low-fidelity prototyping tool and conducted user studies of how designers build a prototype. These studies were foundations of our new prototyping tool design. Our prototyping system is a concept and a prototype that supports designers in building interactive low-fidelity prototype, especially when building an interactive wireframe. Previous work have thought of this type of prototyping tool, however they have limits in requiring extra behaviors for designers such as photographing user interface sketches or resizing photos. Our system addresses this challenge by adopting a pen-and-paper interaction. By adopting the .Code technology, we bridged the gap between a digital world and a paper world.

Through the preliminary study, we found that a user interface flow of wireframe prototype is important rather than design details. Although the wireframe prototype mostly used in an early phase of design process, it rarely respond to users' interaction. Therefore, we focuses on a supporting interaction between user interfaces' screen transitions. Whereas previous work has done this work on a digital tablet, our prototype tool provides the interaction technique that enables designers giving screen transition interaction with a digital pen and a paper. We designed a template paper and implemented a pen mode in the system, and the combination of these designed paper and the pen-mode defines a designer's pen interaction. By doing so, our tool lets designers build a prototype with pen-and-paper interaction only. In the following paragraphs, we describe the pen-and-paper interaction in the system and introduce how to give interactivity to a wireframe prototype.

4.1. SYSTEM OVERVIEW

Our prototyping system aims at augmenting interactivity in low-fidelity prototyping. By setting up the screen transitions on user interface sketches with a digital pen, designers increases interactivity by hand-drawing. Also, designers can quickly check their interactive wireframe on a mobile device. This will increase the communications between other people.

Designers draw their user interface sketches on a pre-defined template papers. A template paper is designed to interact with a digital pen, called “Neo1”. Special patterns of codes are printed on a template papers. With these patterns, a digital pen can track the designer’s sketching behaviors on a template paper. As designers draw a wireframe, a digital pen receives dot information and combining it into stroke and sends stroke data to a mobile device, and the application in the device, handles the data.

FIGURE 4. NEO 1 DIGITAL PEN

With these data, the application defines the pen interaction. It is defined by the pen mode data and stroke location data, and stroke location data is defined by the template design. According to the pen interaction, the application decides whether this stroke is related to sketching or linking. When designers convert a wireframe into a mobile device, the application fetches the stroke data and redraws the sketches and set clickable areas on the mobile device.

4.2. PEN MODE

To supports the designers' natural sketching behaviors, we need to classify the designers' sketching behaviors whether they sketch or not. However, classifying drawing behavior is as hard as letter recognition. Therefore, we need to classify the pen interaction physically. We offer the pen mode concept on a digital pen: drawing mode and linking mode. Depending on the pen mode, stroke information from a digital pen is handled differently. If the designers draw strokes with drawing mode, a mobile application stores all the strokes as user interface sketches. On the other way, with the linking mode, the mobile application classifies the designers' input strokes depending on the stroke location data because, in linking mode, designers' drawing actions are defined by the positions of the strokes. The details are explained following paragraphs. To support the intuitive interaction technique, we set the pen mode change by simply tapping the digital pen-tip in the specific area of the template page. We set the mode change by tapping the extra area of the template paper.

FIGURE 5. PEN MODE SCREEN. WHEN USER TAPS THE EXTRA AREA, THE PICTURE SWITCHES EACH OTHER

4.3. A TEMPLATE PAPER DESIGN.

We designed a template paper to supports the natural pen behaviors. The template paper is divided into three areas: design area, extra area, and anchor area. Design area is defined in a screen area of a template page, which is for sketching user interfaces. A screen area has the same size of real device. Designers draw their wireframe in this area. Anchor area is a special area that is only for a linking action. The anchor area has seven anchors that are corresponding to one clickable area. The explanation of the anchor area is explained in the following paragraph. Figure 7 illustrates a usage of extra area. Designers can annotate and scribble in the extra area, or use for pen-mode changing.

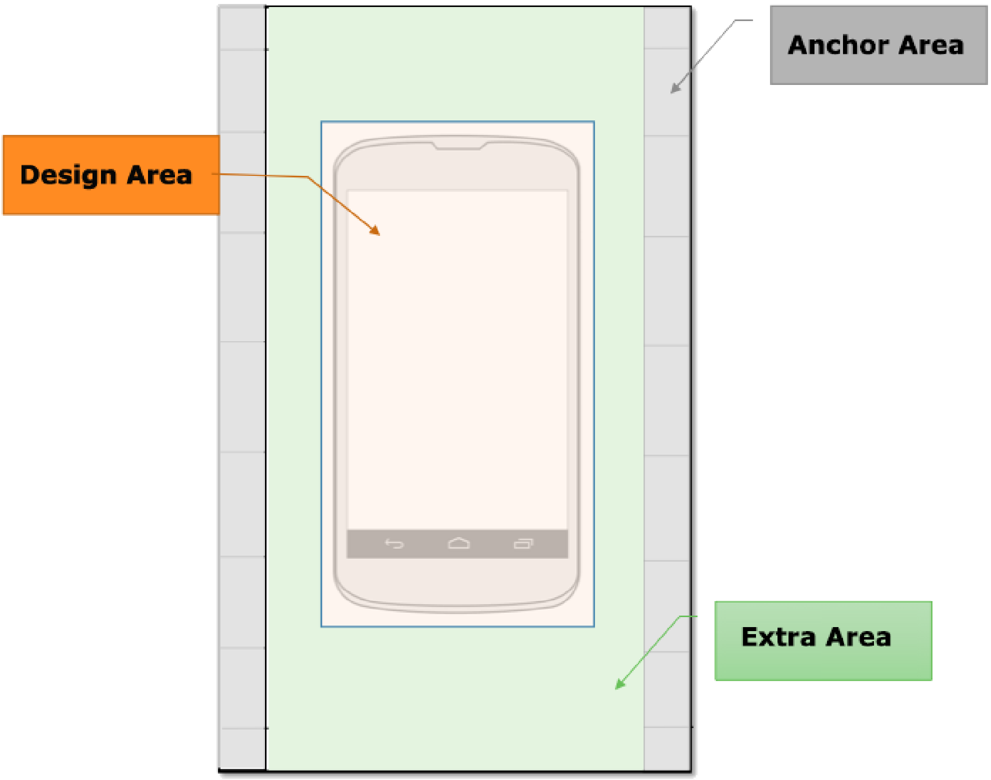

FIGURE 6. TEMPLATE PAPER DESIGN

4.4. DEFINING A PEN INTERACTION

Depending on the pen mode and the stroke's location information, designers' pen interaction is defined. Pen interactions are categorized into four: i) drawing, ii) boxing, iii) anchoring, and iv) linking. With these four primitive interactions, we implemented the whole interactions.

4.4.1. *DRAWING*

Sketching user interfaces is same as the natural behavior which designers do. Designers just draw whatever they want to express on the design area. Drawing outside the designer area or across the design area and other area does not affect the digital output; however, it remains on the physical paper, so the designers can utilize the extra area as an annotation section.

4.4.2. *LINKING*

Linking is consisted of three primitive interactions: boxing, anchoring, and linking. Only the exact sequence of those three primitive interactions can make a link between a user interface and other screen. Basically, when drawing user interfaces, it is impossible to distinguish a clickable user interface from others because we do not support a gesture recognition technique. Therefore, we make a chain of interactions to support the linking action.

1. At first, designers perform the boxing interaction on the design area. Since the boxing is the behaviors of selecting a specific area, we defined the boxing when the designers draw a rectangular or mark brackets at the top-left and bottom-right corners on the design area.

2. After the designers set the box for clickable area, they perform the anchoring interaction. By drawing a line between the box and the anchor sections, a clickable area is anchored to the anchors in anchor area. Because

there are only seven anchors on a template paper currently, designers make seven links per one paper.

3. Finally, designers overlapped the other template paper, which will be the next screen when click, and draw a line across the anchor area and the extra or anchor area on the other paper.

If designers fail to complete the above interaction sequence, the linking action will be canceled, and designers have to restart the whole sequence from the first part. In this perspective, learning this sequence might be the difficulty in using our prototyping tool.

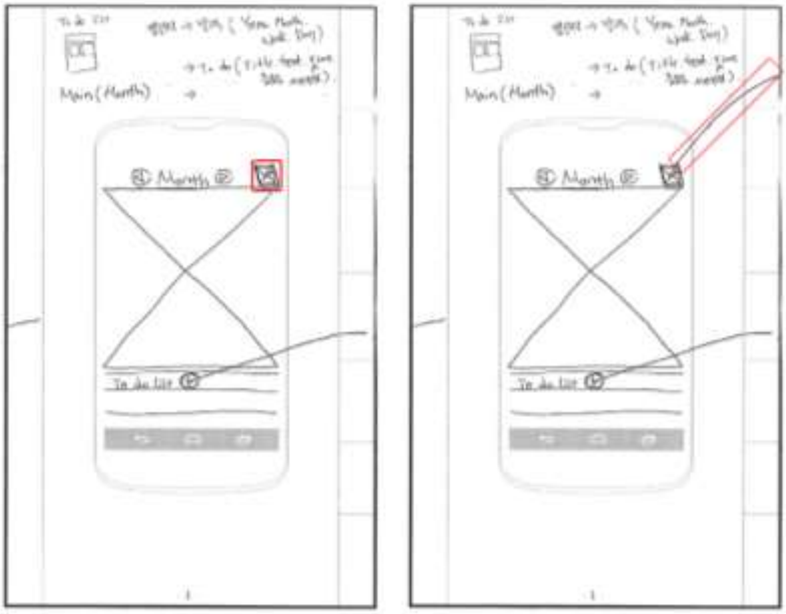

FIGURE 7. BOXING AND ANCHORING MOTION

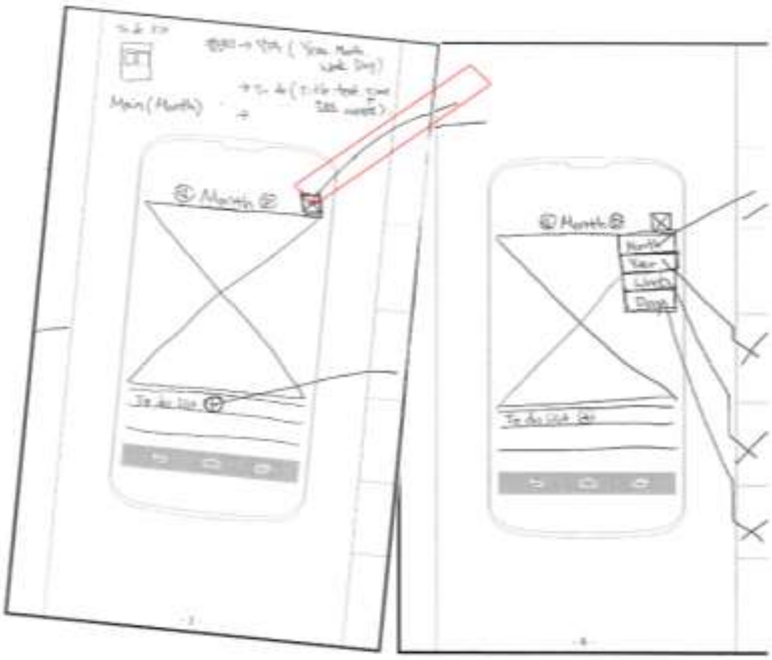

FIGURE 8. LINKING MOTION

5. IMPLEMENTATION

Our prototype consisted of a mobile application and Neo1 digital pen. A mobile application was implemented on the Android platform using Java SE 1.7. Figure 9 shows the overall architecture of our prototype. A database is embedded in the android application and used for storing stroke information. Once the digital pen tip is down to the template paper, the pen starts to track the pen movements. The pen stores all the x, y coordinate information as a dot structure. When the pen tip is up, the pen sends the stroke data to the mobile application. In the following, we describe the components of our system.

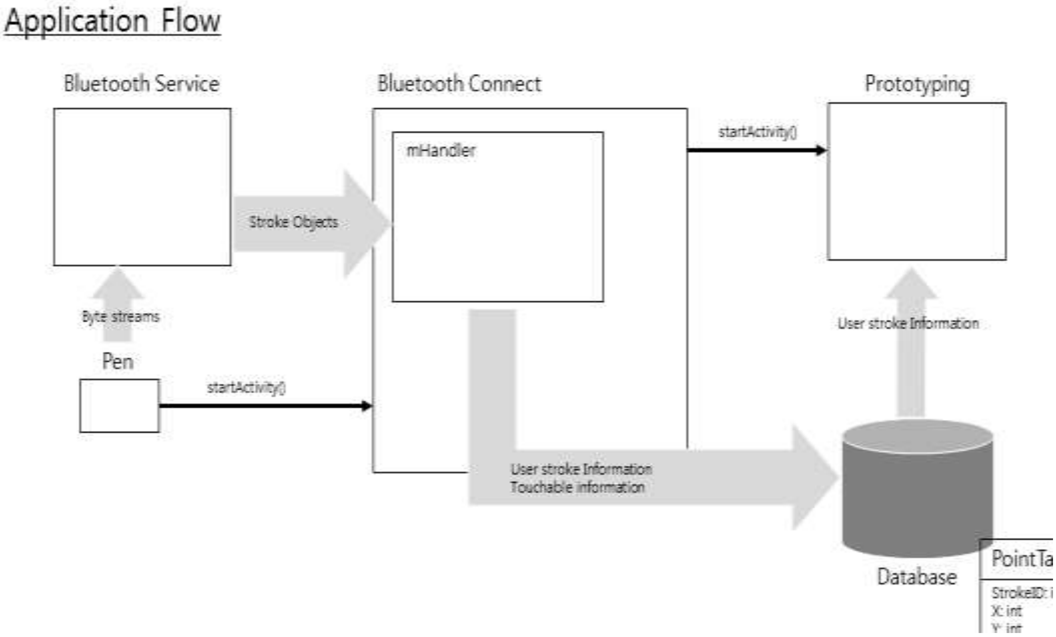

FIGURE 9. OVERALL ARCHITECTURE OF THE SYSTEM

5.1. DATA STRUCTURE

Figure 10 depicts a data structure used in the system. The data structure represents the concept of physical and digital information. When designers sketch user interfaces on a template paper, a digital pen sends the current point on the template page as Stroke class. The Stroke class data contains a list of dot objects, page id, and note id; the page id and note id represent where the stroke comes from. Once, the stroke object is transmitted to the application, the application constructs the SketchArea class. This class presents a designer’s sketches as digital information with a list of stroke, page id, note id, and the touchable areas. Unlike the SketchArea class, TouchableArea presents the clickable area where the designers marked on a template paper with boxing action. With the SketchArea and TouchableArea, the application can reproduce the physical user interface sketches on a mobile device screen.

The Android device basically supports a hardware back button, so a user can go back without a navigation user interface. However, hardware back button in our prototyping application used for changing mode between running a prototype and receiving stroke data. Thus, to give a realistic mobile device usage experience, we build ViewStack class, which contains an information of each user interface sketches presenting in the mobile device. By saving the information about which sketches are shown in the device, the application could support the hardware navigation. But at this moment, this function has not been developed yet.

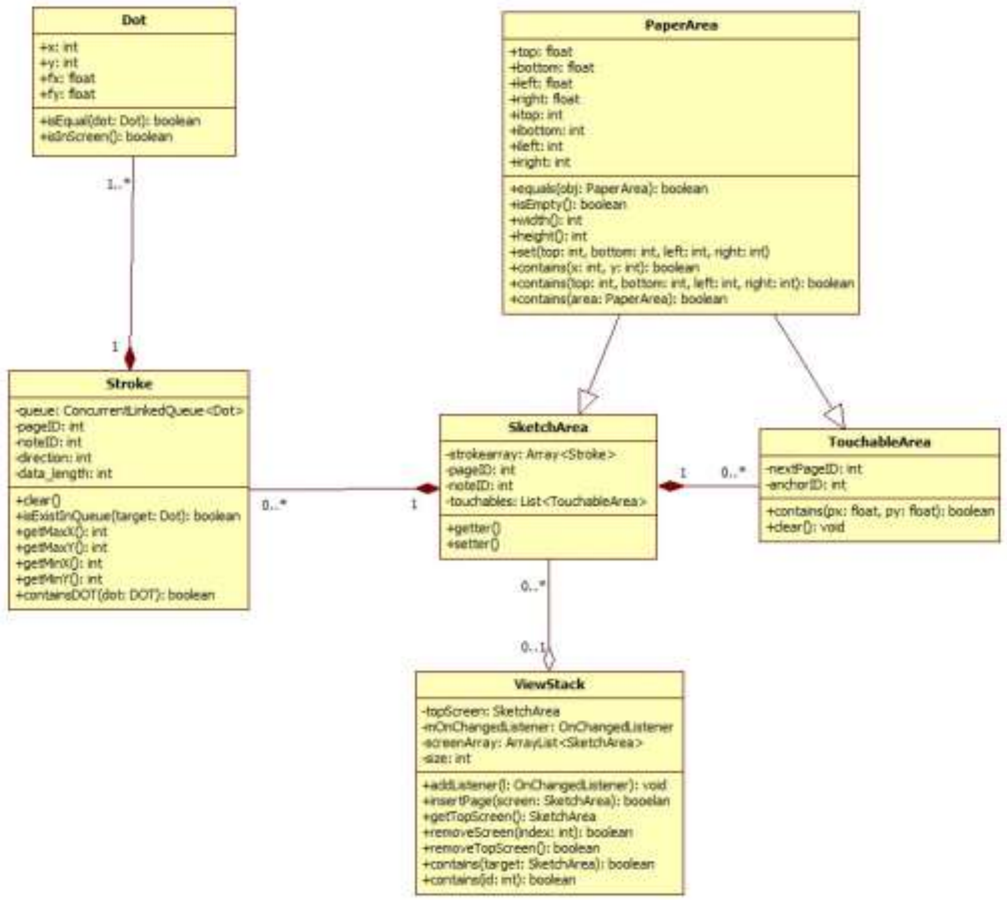

FIGURE 10. DATA CLASS DIAGRAM

5.2. PEN INTERACTION STATE

We define six pen interaction states using the stroke information and the pen mode. Depending on the pen mode and the stroke's location information, the mobile application classifies the designers' pen interaction and handles the input. The stroke's location information includes the points where the pen tip is down and up. Although, there are many possibilities of the combinations, not all combinations are used, and some combinations defines the same pen interaction. Table describes the cases of combinations of the pen mode and stroke information. The “n/a” state do not affects the digital output, but they are remained in physical papers.

Start point	**End point**	**Drawing mode**	**Linking mode**
Design	Design	Drawing	Boxing
Design	Extra	n/a	n/a
Design	Anchor	n/a	Anchoring
Extra	Design	n/a	n/a
Extra	Extra	Mode changing	n/a
Extra	Anchor	n/a	n/a
Anchor	Design	n/a	n/a
Anchor	Extra	n/a	Linking
Anchor	Anchor	n/a	Linking

TABLE 1. PEN MODE AND STROKE COMBINATION TABLE

6. USER EVALUATION

6.1 STUDY OVERVIEW

The main goal of user evaluation was to assess the ease of use of the prototyping tool and of interaction technique for page linking. User satisfaction was measured by questionnaires in order to examine whether the prototyping tool is acceptable by designers.

6.2 STUDY PROCESS

Eight participants (F=7, M=1) were invited to the evaluation study. All of them have a minimum one year of user interface design experience in profession (Avg. = 2.5). Five of the eight were considered having user interface design expertise and three were considered having user experience design expertise.

Each participants performed one training task and two main tasks in a controlled environment. They were sat in front of desk and performed the tasks. One video camera and one voice recorder had recorded participants' behavior. In each task, participants were provided a digital pen, template papers, and a mobile device. No time limit on the experiment was enforced. For each participant, they read the basic information about the evaluation first. Then, the study began by having the participant sign consent form (APPENDIX A).

The evaluation session started with training session. In training session, participants listened to instructions of the prototyping tool. After listening, participants were asked to complete the following tasks: i) draw a button in the given two papers each; ii) make a link between two papers; iii) convert the sketches and check them on a mobile device.

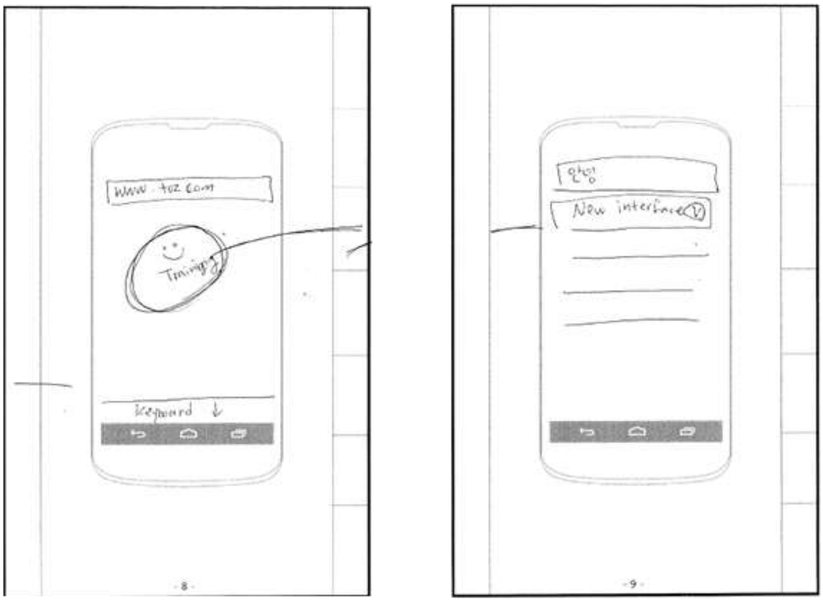

FIGURE 11. OUTPUT OF TRANING SESSION

Following the training session, the participants were asked to complete main tasks. The main tasks are consisted of following program: i) Prototyping an existing mobile application user interface and ii) Designing and prototyping a user interface of a schedule application. After completing each task, they were asked to interview about the feelings of using prototyping tools. Lastly, they were provided with questionnaires as a part of the follow up evaluations. (See the Appendix B).

6.2.1 TASK 1

Task1 is building a prototype of existing user interfaces using the prototyping tool. We choose one mobile application and capture its user interface screen. Among the captured user interface screens, seven of them were provided to participants (Figure 12). The photos used in task 1 provided in Appendix C. The provided photos represent the sequence of information flow of the application user interface with marks and arrows. An orange circle presents a clickable area in the screen, and relationships between each user interface element and a user interface screen were depicted using arrow lines. These circles and lines represent the touch events that the designers intended to occur. Performance time was measured, and according to Think Aloud Protocol, participants were encouraged to speak out their feelings. The participants' activities and utterance were recorded and transcribed for further discussions.

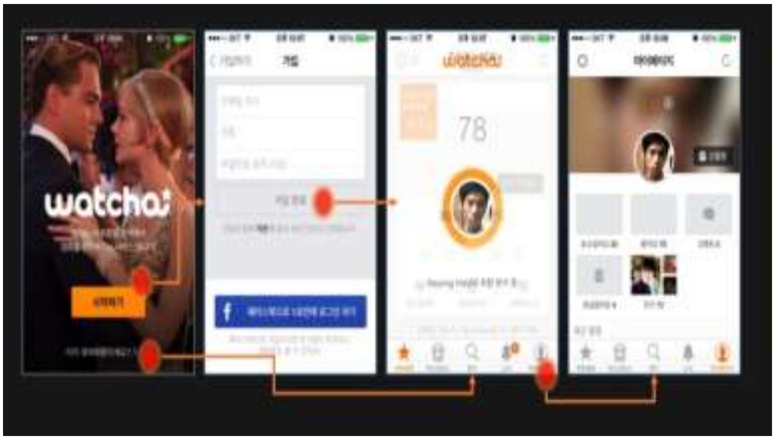

FIGURE 12. EXAMPLE OF PROVIDED PHOTO IN TASK 1

6.2.2 Task 2

In task 2, participants were asked to design and prototyping user interfaces of their own schedule application. All participants were asked to make a low-fidelity wireframe prototype with given materials. The number of user interface screen was limited to 5 to 7, but no design details were restricted. In common with the task 1, participants were asked to follow Think Aloud Protocol during the task. Task completion time measured, and the participants' activities and utterance were recorded and transcribed.

6.2.3 QUESTIONNAIRES

After the experiment session, questionnaires were provided to get feedbacks from subjects. The questionnaires were designed referring to the post-study system usability questionnaires (PSSUQ), which were developed by IBM, to evaluate the prototyping tool. The questionnaires contained three items for demographic and eight-teen items for measuring the usability of application across the following factors: Easy of learning; satisfaction; usefulness; ease of use; level of fidelity. The contents of questionnaires are listed in Appendix.

6.3. RESULTS

The evaluation results include quantitative result – performance measure, descriptive observations, and the comments from in-session and post-interviews. Since we proposed a brand new prototyping tool and interaction technique, we mainly focused on a qualitative data (e.g. observation data, interview data). The interview and observation data are given in terms of three main objectives.

- Sketching User Interface: The data about drawing user interfaces or drawing behaviors.
- Pen mode change: The data about pen usage.
- Navigating User Interface (Screen Transition): The data about the interaction technique or behaviors during the building screen transition interaction.

6.3.1 Sketching user interfaces

Since participants used a physical pen to make a wireframe, they did not have any difficulty in drawing a wireframe on a template paper. As shown in Figure 13, they drew various design alternatives, it shows that our prototyping tool supports the creativity in prototyping, and it shows our prototyping tool fulfills the requisites of a low-fidelity prototyping tool.

However, they indicated some weaknesses of the current prototyping tool also. Most of them said that when they sketched tap-like user interface, it was tedious to sketch the same user interface widget repeatedly. They said that it would be better if there were a way of using predefined user interface widget. Also, they pointed out that current system did not support to revise the wireframe.

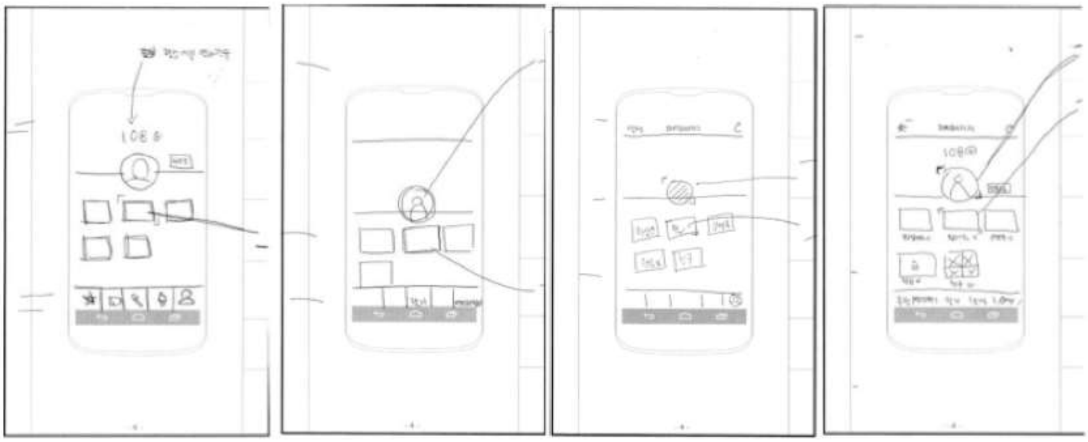

FIGURE 13. USER INTERFACE SKETCHES OF SAME PHOTO

Many designers mentioned that they were frustrated that whether their sketches were transmitted properly into the mobile device. Some participants pushed the 'convert' button very often to check their UI sketches. We conclude that this result came from the fact that there was no feedback in our system and they were under pressure of failure because they could not revise their sketches.

One of the interesting results is that participants looked like using a digital tablet device. They checked the mobile device often, and pay attention to sketching like designing visual details not like rough sketch. We found that the difference between a participant who seemed like using a tablet device and a participant who seemed like to pay attention to the paper only was the distance between the participants and the mobile device. In latter case, participant put the mobile device far from himself. In the interview, he said the reason why he put the mobile device far way was to focusing on the sketching on paper thoroughly.

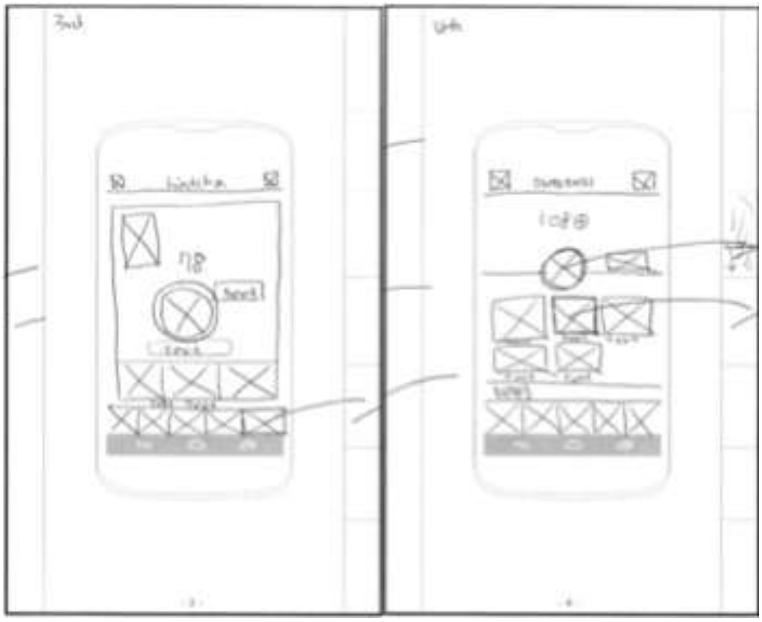

FIGURE 14. AN EXAMPLE OF OUTPUT

6.3.2. PEN MODE CHANGE

Since the designers are very natural to draw with a pen, there were no feedbacks about the pen interaction during the drawing. So, the feedbacks about using pen are the pen mode change only.

To navigate user interfaces, participants have to change the pen mode from drawing mode to linking mode. The changing motion, tapping the paper, is quite intuitive, but the participants felt that changing a pen mode was not convenient at first. However, they fully learned this interaction only after the several practicing. Once they had learned, they had no difficulty in changing the pen mode, but recognizing and remembering the pen mode made them distracting consistently. Sometimes participants for got what the pen mode was, especially when they focusing on sketching. In the interview, they said recognizing the pen state continuously was hard. They also had difficulty in annotating in the extra area. Because we set the one tap-motion changed the pen mode, annotating in the extra area led many changes in the pen mode. For example, when they make an annotation, the participants do not know what the pen mode is now.

6.3.3. Navigating user interfaces.

Overall steps of navigating user interfaces were very difficult to learn. Among the interactions related to the navigating, anchoring and linking were the most confusing. One of the participants said that unlike the drawing action, anchoring and linking action were not the actions he/she had done before when they draw a wireframe.

The output lines of navigating activities became a drawback in the system. Most participants expressed annoyance about the lines. After they made link-lines on sketches, the lines made the sketch messy as shown in Figure 15. Because the anchor sections are located in the right edge of the template paper, they should draw the line across the sketch when they link the right-positioned user interface element. Even though they can make links by drawing link−lines around the device picture in the template (Figure 16), these lines also make the sketch messy in total.

In prototyping a schedule application, many participants were faced with the reusable problem. They made many exit points in a ‘add task’ or ‘add schedule’ user interface (Figure 17). However, in the current system, the anchors have only one pointer. Therefore, they had to draw the ‘add task’ or ‘add schedule’ user interface each case in detail.

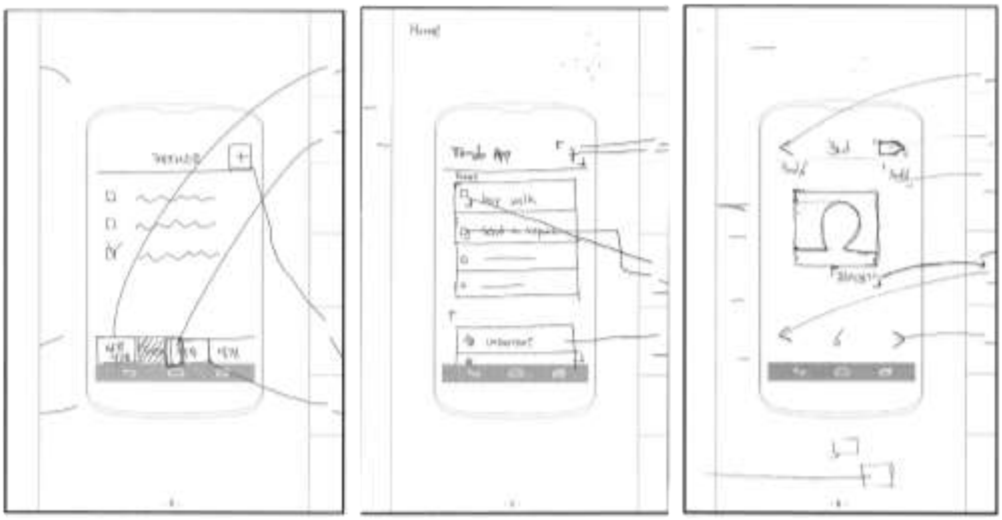

FIGURE 15. MESSY USER INTERFACE SKETCHES

FIGURE 16. DRAWING A LINK LINE AROUND THE DEVICE

In prototyping a schedule application, many participants were faced with the reusable problem. They made many exit points in a ‘add task’ or ‘add schedule’ user interface (Figure 17). However, in the current system, the anchors have only one pointer. Therefore, they had to draw the ‘add task’ or ‘add schedule’ user interface each case in detail.

FIGURE 17. 'ADD TASK' USER INTERFACE SKETCHES

6.4 DISCUSSION

The results of evaluations told us both positive and negative aspects about our prototyping tool. Overall, designers satisfied the ease of use and the level of fidelity. They felt the fidelity of the prototype using our tool is quite interactive, and the performance of our prototyping tool is useful to prototype. Most of them were very surprised that they can view their sketches on a mobile device instantly, and they were interested in using the tool in their own project.

Although the entry barrier is somewhat higher than we expected, the result of user evaluation indicates that once the participants learned, the interaction technique of the prototyping tool was intuitive and adoptable, especially the pen interactions – changing pen mode, boxing.

Since our prototyping tool is not the computer-based prototyping tool. The advantages of computer-based prototyping tool become the disadvantages of our tool. First, designers cannot revise the user interface sketches in our prototyping tool because the designers use a ballpoint pen in sketching a wireframe. Even it they can revise the sketches using the special ballpoint eraser, they can only revise the paper sketches not the digital prototype. In current system, once they sketch user interfaces in the template paper, the sketch data is transmitted to the mobile application. To revise the sketch, they have to redraw the sketch on another paper. Moreover, because our tool is based on a pen-and-paper interaction, copy-and-paste is not easy, which is very easy in computer-based tool. This led the tab-like user interface problem mentioned in section 6.3.1. Another reusable problem is occurred in navigating. As mention in section 6.3.3, when certain user interface has many exit points in information flow, e.g. confirm dialog, the designers have to draw the each user interface one by one because the anchors has only one pointer in current system. All of these problems lead designers under pressure of the possibility of failure.

Some designers expressed anxiety in prototyping. They checked their sketches on mobile device frequently and pretended to draw the sketches too discreetly. We supposed that this comes from no immediate feedback of drawing actions. They felt that they should complete the sketches without failure.

Interestingly some participants looked like using a tablet device. They checked the mobile device often, and pay attention to sketching like designing visual details not like rough sketch. Since the distance between the designer and the device might affect them, we will test an influence of the distance in the following research.

When interviewing the participants, the most possible reason of not using our prototyping tool is the navigating interaction. As shown in result section, after navigating the user interfaces with other user interface screens, the wireframe sketches were become messy. Since the designers can check their design on a mobile device instantly, we had not considered this problem at the start. But participants appealed that they will check the interactions with papers before converting the sketches into a mobile device, and they check the overall flow with the papers because they could see the papers at a look.

FIGURE 18. USER INTERFACE THAT HAVS MANY EXIT POINTS

7. CONCLUSION

In this paper, we introduce the prototyping tool that builds a prototype instantly from the user interface sketches. The benefits of this study are that our prototyping tool allows designers make an interactive prototype from their sketches. By using the *.Code* technology, our prototyping tool overcomes the drawback which previous prototyping tool have; previous tools requires the additional efforts to designers or do not support hand-drawn sketches. Unlike the other paper prototypes, our tool allows the designers to interact with their prototypes on a mobile device. The user evaluation result showed that designers indicated preference to use our prototyping tool – they were surprised at converting their sketches into a mobile device instantly and wanted to use in their project. With this tool, designers draw user interfaces, make links between them, and discuss them with other team member with easy.

However, the prototyping tool still has limitations also. One of the limitations is refinement. Because our tool use ballpoint pen and does not the advantages of computer-based tool, modifying action is almost impossible during the prototyping. Although the designers can redraw the user interface design on other paper, they may feel inconvenient. Another limitation is the difficulty in learning. The linking sequence – boxing, anchoring, and linking – is quite confusing because the designers should follow the exact sequence of pen interactions. When they following the wrong sequence of pen interactions, they failed to see an interactive prototype that they intended at the start.

Because we discovered that the interaction techniques has a problem in building interactive prototyping, future research will focus on developing a novel way of linking actions between sketch papers. To get rid of the messy link lines in sketches, we are considering adopting a pen gesture recognition technology. If we implement the pen gesture recognition technology, future system will make the link by writing a paper number. Further, future research considers pre-defined user interface widget. Pre-defined user interface widget is expected to reduce the time in building a prototype with better look and function compared to current prototyping system.

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APPENDIX

APPENDIX A: SIGN CONSENT FORM

IRB No. 1309/001-016　　　유효기간: 2014년 9월 12일

연구참여자용 설명서 및 동의서

연구 과제명 : 　인터랙티브 페이퍼프로토타이핑 툴 제작에 관한 연구
연구 책임자명 : 서울대학교 인문대학 협동과정 인지과학 하세용 연구원.

이 연구는 인터랙티브한 페이퍼프로토타이핑 툴에 대한 사용성 평가를 목적으로 하고 있습니다. 귀하는 UX디자인 경력이 1개월 이상이며, 페이퍼프로토타이핑을 5회 이상 해본 경험을 갖고 있습니다. 이러한 사실에 따라 귀하께서는 본 실험에 참여하실 수 있게 되었습니다. 본 연구의 책임자는 하세용 연구원이며(tel: 010-2061-5071, email: aicarin@snu.ac.kr), 본 연구에 관한 질문 사항은 담당연구원에게 질문해주시기 바랍니다. 이 연구는 자발적으로 참여 의사를 밝히신 분에 한하여 수행될 것이며, 귀하께서는 참여 의사를 결정하기 전에 본 연구가 왜 수행되는지 그리고 연구의 내용이 무엇과 관련 있는지 이해하는 것이 중요합니다. 다음 내용을 신중히 읽어보신 후 참여 의사를 밝혀 주시길 바라며, 필요하다면 가족이나 친구들과 의논해 보십시오. 만일 어떠한 질문이 있다면 자세하게 설명해 줄 것입니다.

1. 이 연구는 왜 실시합니까?

인터랙티브한 페이퍼프로토타이핑 제작을 위한 툴이 실제 사용자들에게 어떠한 영향을 미치는 지 알아보고 툴을 개선해보고자 합입니다. 또한, 본 실험 결과로 모바일프로토타이핑에 인터랙티비티가 미치는 영향을 알아보고자 합니다.

2. 얼마나 많은 사람이 참여합니까?

전화와 이메일을 통해 모집한 약 20여명의 참여자가 있을 예정입니다.

3. 만일 연구에 참여하면 어떤 과정이 진행됩니까?

만일 귀하가 참여의사를 밝혀 주시면 다음과 같은 과정이 진행될 것입니다.

1) 귀하는 연구 참여에 앞서 제작된 툴의 사용법에 대해 사전 강습을 받게 됩니다. 사전 강습은 5분 가량 진행됩니다.

2) 이후 귀하는 준비된 Task목록을 읽고 제작된 툴을 사용하여 Task를 수행하면 됩니다. Task를 수행하는 동안에는 Think Aloud Protocol에 맞춰 귀하의 의견을 직접 말하도록 요구받을 것입니다. Think Aloud 방법이란 실험에 참여하면서 느낀 바 혹은 머릿 속에 떠오른 바를 자연스럽게 밖으로 말하는 것을 말합니다. 따라서 귀하는 Task를 수행하면서 느낀바, 머릿속에 떠오른 바를 자연스럽게 밖으로 말하면 됩니다. 　귀하가 제공된 툴을 이용하여 프로토타입을 제작하는 화면과 귀하의 목소리는 비디오 녹화됩니다.

3) 모든 Task의 수행이 끝난 뒤에 귀하는 제공되는 설문조사 항목들에 대한 답을 하도록 요구받을 것입니다. 제시되는 설문조사 항목은 제작된 툴에 대한 귀하의 만족도를 평가합니

APPENDIX B : QUESTIONNAIRES

IRB No. 1309/001-016 유효기간: 2014년 9월 15일

인터랙티브 페이퍼프로토타입 제작 툴에 대한 설문조사

안녕하세요, 연구의 설계와 진행을 맡은 서울대학교 인문대학 협동과정 인지과학 하세용 석사연구원입니다. 본 연구의 목적은 인터랙티브 페이퍼프로토타입 제작 툴의 사용에 있어서 제작자들의 만족도를 평가하기 위함입니다. 이 설문은 실제 사용자들이 생각하는, 제작툴에 대한 만족도를 측정함에 있습니다. 이에 대한 연구는 오프라인 설문조사의 형태로 진행되며 참여하시는 분들은 제작툴에 대해 준비된 설문항목에 답을 하도록 요청 받을 것입니다. 설문조사는 총 10 분 내외의 시간이 소요될 예정입니다. 연구에 참여하시는 분 들에게는 모두 5,000 원의 참여 비를 지급해 드립니다. 연구에 대한 질문이 있으신 경우 연구 책임자인 서울대학교 인문대학 협동과정 인지과학 하세용 석사 연구원에게 (010-2061-5071 / alcarin@snu.ac.kr) 연락해 주시기 바랍니다. 많은 참여 부탁 드립니다. 감사합니다.

서울대학교 인문대학 협동과정 인지과학 하세용 석사 연구원

Version 1.2 (2013.11.5)

1. 펜의 모드 변환을 빨리 학습했다.

(매우 그렇지 않다)　　(매우 그렇다)

1　2　3　4　5　6　7

2. 학습단계에서 알려준 Pen 의 기본동작을 쉽게 학습할 수 있었다.

(매우 그렇지 않다)　　(매우 그렇다)

1　2　3　4　5　6　7

3. 제작물을 쉽게 응용할 수 있었다.

(매우 그렇지 않다)　　(매우 그렇다)

1　2　3　4　5　6　7

4. 나는 이 도구에 만족한다.

(매우 그렇지 않다)　　(매우 그렇다)

1　2　3　4　5　6　7

5. 나는 이 도구를 프로젝트에 사용할 의향이 있다.

(매우 그렇지 않다)　　(매우 그렇다)

1　2　3　4　5　6　7

Version 1.2 (2013.11.5)

6. 이 도구는 내가 표현하고자 하는 바를 충분히 충족시킨다.

(매우 그렇지 않다) (매우 그렇다)

1 2 3 4 5 6 7

7. 이 도구는 빠른 prototyping 을 가능하게 해준다.

(매우 그렇지 않다) (매우 그렇다)

1 2 3 4 5 6 7

8. 이 도구는 prototyping 을 더욱 쉽게 할 수 있게 해준다.

(매우 그렇지 않다) (매우 그렇다)

1 2 3 4 5 6 7

9. 이 도구는 prototyping 에 있어 필요한 기능을 모두 지원한다.

(매우 그렇지 않다) (매우 그렇다)

1 2 3 4 5 6 7

10. 이 도구는 내가 기대하는 기능을 모두 지원한다.

(매우 그렇지 않다) (매우 그렇다)

1 2 3 4 5 6 7

11. Pen Interaction 은 매우 직관적이다.

(매우 그렇지 않다) (매우 그렇다)

1 2 3 4 5 6 7

12. 이 도구는 매우 친숙하다.

(매우 그렇지 않다) (매우 그렇다)

1 2 3 4 5 6 7

13. 이 도구는 내가 하려는 바를 적은 단계만을 거쳐서 수행할 수 있게한다.

(매우 그렇지 않다) (매우 그렇다)

1 2 3 4 5 6 7

14. 매뉴얼 없이 이 도구를 사용할 수 있다.

(매우 그렇지 않다) (매우 그렇다)

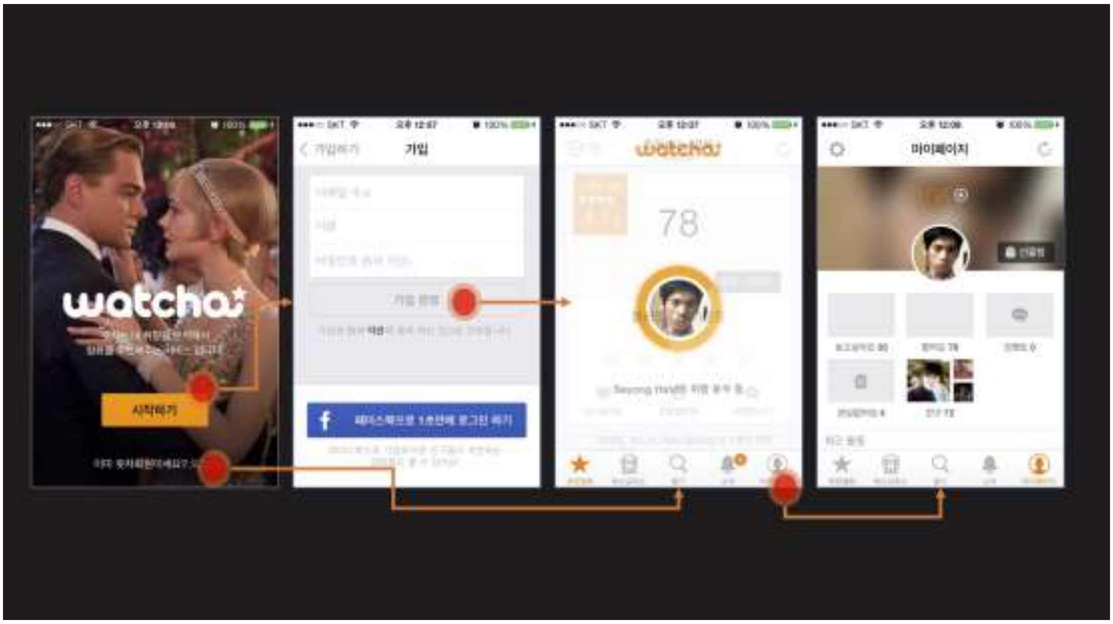
1 2 3 4 5 6 7

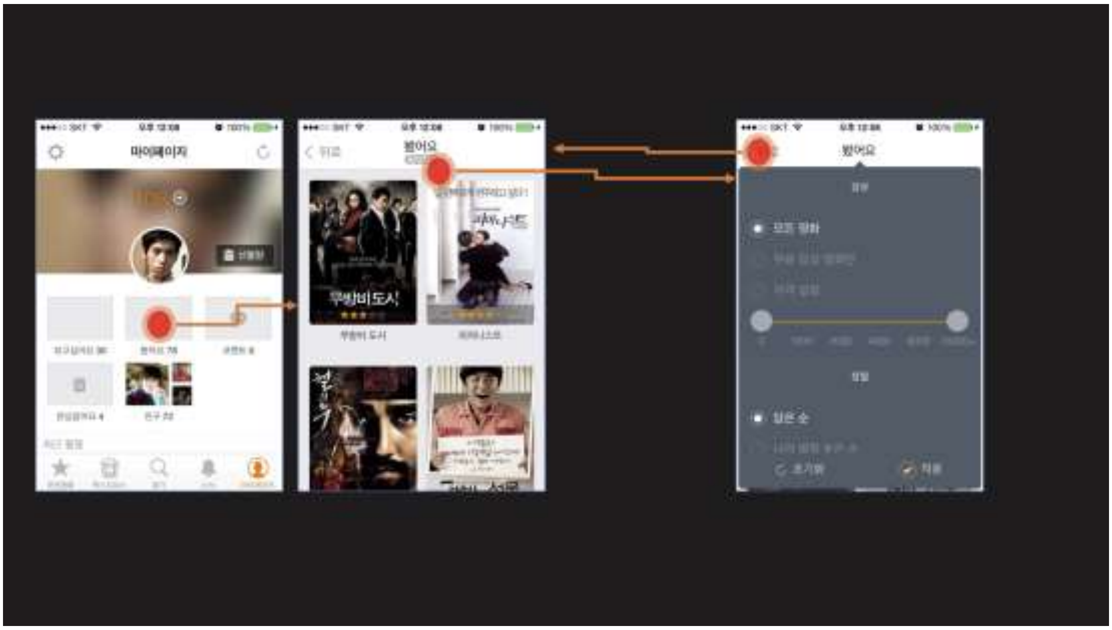
15. 잘못된 행동으로부터 빠르게 복구할 수 있다.

(매우 그렇지 않다) (매우 그렇다)

1 2 3 4 5 6 7

APPENDIX C: TASK1 MATERIALS




마이페이지
봤어요
무방비도시
봤어요

국문초록

Augmenting Interactivity of low-fidelity paper prototypes

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오늘날 사용자 인터페이스(User Interface) 디자인은 빠르고 반복적인 디자인으로 대표된다. 빠르고 반복적인 디자인은 각 디자인 단계마다 사용자 테스트를 동반하고 이러한 사용자 테스트는 현재 단계의 디자인에 대한 피드백으로 이어진다. 디자인 단계가 지나갈 때 마다 그 단계의 디자인에 대한 피드백이 이루어 지기 때문에 반복적인 사용자 테스트는 사용자 인터페이스의 전반적인 품질 향상을 가져온다. 반복적인 디자인에 있어 각 단계마다 다양한 종류의 프로토타입(Prototype)이 사용자테스트를 위하여 사용된다. 예를 들면, 매우 앞 단계의 디자인에서는 로우-피델리티(Low-fidelity) 프로토타입이 사용되는데, 이는 로우-피델리티 프로토타입이 제작과정과 그 비용에 있어서 매우 빠르고 저렴하기 때문이다.

하지만, 많은 비용을 들이지 않고 빨리 만들기 때문에, 사용함에 있어서 인터랙티비티(Interactivity)부분이 많이 떨어진다. 로우-피델리티 프로토타입 중에 가장 흔히 사용되는 것은 와이어프레임(Wireframe)이다. 하지만, 이것 또한 아까 언급했던 것처럼 인터랙티비티를 주는 데에 있어 약점을 보이기 때문에, 사용자에게 실질적인 사용 경험을 주기는 매우 어렵다. 우리는 이러한 부분을 보완하는 인터랙티브한 로우-피델리티 프로토타입 제작 도구에 관하여 연구하였다.

문헌 조사를 통해, 현재 사용되는 상업 도구에 대하여 조사하고 그 한계점들을 알아보았다. 또한, 사전 실험을 통해, 프로토타입 제작 툴을 만듦에 있어서 꼭 필요한 조건들을 미리 찾아보고, 제작 방향에 대하여 논의해보았다. 문헌조사와 사전 실험을 바탕으로 우리는 모바일 어플리케이션(Mobile Application) 사용자 인터페이스 디자인을 위한 프로토타이핑 제작 도구를 만들었다. 본 제작 도구는 네오원(Neo1)이라 불리는 디지털 펜과 특수한 종이, 그리고 안드로이드 기반의 모바일 어플리케이션으로 만들어졌다. 사용자들은 네오원 펜을 사용하여 특수종이에 와이어프레임을 그리고 이것을 모바일 어플리케이션에서 변환하여 직접 모바일 디바이스 상에서 테스트해볼 수 있다. 닷코드(.Code)라 불리는 기술을 사용하여 디자이너들의 펜 움직임을 추적하였고, 이는 디자이너들이 사용자 인터페이스를 그리고 인터랙티비티를 부여하는 동작을 쉽게 하였다. 박싱(Boxing), 앵커링(Anchoring), 링킹(Linking) 인터랙션을 통해 디자이너들은 자신이 그린 사용자 인터페이스의 스크린 사이의 화면 전환을 부여할 수 있다.

마지막으로 우리는 본 제작 도구에 관하여 사용자 테스트를 실시하였다. 8 명의 참여자를 대상으로 2 가지 프로토타이핑 실험을 진행하였다. 실험 도중과 실험이 끝난 후 사용자의 피드백을 모아, 제작도구에 관한 반응을 알아보았다. 사용자 테스트 실험 결과는 본 제작

도구에 관한 좋고 나쁜 의견 모두를 전해주었다. 실험 참여자들은 본 도구가 인터랙티브한 프로토타이핑을 함에 있어 매우 유용하다고 피드백을 주었지만, 본 도구에서 사용한 인터랙션 방법에 있어 향후 연구에서 수정되어야 할 몇 가지 부분 또한 지적해주었다.

주요어 : 인터랙티브 프로토타입, 로우-피델리티, 와이어프레임, 펜 인터랙션

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